CLAIMS

1. A method of producing nitride films comprising:

(a) providing first and second electrodes,

(b) applying a voltage between said first and second electrodes to establish a corona discharge therebetween,

(c) introducing nitrogen into the corona discharge under pressure to activate the nitrogen and to direct the activated nitrogen toward a substrate, and

(d) applying the activated nitrogen to the substrate in the presence of at least one further element to form a nitride film.

2. The method according to claim 1, wherein the one further element is selected from the group consisting of Al, Ga and In.

3. The method according to claim 2, wherein step (d) comprises introducing the at least one further element to the substrate at the location of application of the activated nitrogen to the substrate.

4. The method according to claim 1, wherein, in step (d) the at least one further element is oxygen and the nitride film thus formed is an oxynitride film.

5. The method according to claim 1, wherein the substrate is a semiconductor stratum having an oxide layer thereon and step (d) comprises applying the activated nitrogen to the oxide layer.

6. The method according to claim 5, wherein applying the activated nitrogen to an oxide layer on the semiconductor stratum comprises providing a silicon stratum having an oxide layer for contact by the activated nitrogen.

7. The method according to claim 1, wherein step (c) comprises passing the nitrogen through a corona discharge to create metastable activated nitrogen molecules.

8. The method according to claim 7, wherein the metastable activated nitrogen molecules thus created are of the form $N_2A^3\Sigma_u^+$.

9. The method according to claim 7, wherein the metastable activated nitrogen molecules are diatomic molecules, and step (d) comprises reacting one atom of the diatomic molecules with the at least one further element and disassociating the other atom of the diatomic molecules to remove heat of the reaction.

10. A nitride coated substrate produced by the method of claim 1.

11. A semiconductor device having a coated substrate produced by the method of claim 1.

12. An apparatus for producing nitride films comprising:

(a) a pair of corona-discharge producing electrodes,

(b) a nitrogen delivery path leading to a location at which the electrodes produce a corona discharge, and

(c) means to locate a substrate for deposition thereon of nitrogen activated by the corona discharge.

13. The apparatus according to claim 12, further comprising a nozzle with a nitrogen emersion orifice in the nitrogen delivery path, a first one of the corona-discharge electrodes being proximate the nitrogen emersion orifice of the nozzle, a second of the corona-discharge electrodes being spaced from the nitrogen emersion orifice of the nozzle and the first one of the corona-discharge electrodes, a skimmer located downstream of the nozzle in the direction of nitrogen flow, the skimmer defining an opening to collimate a beam of activated nitrogen

molecules passing therethrough, at least one chamber downstream of the skimmer, means for evacuating the chamber to draw off gases other than the activated nitrogen molecules prior to the activated nitrogen molecules reaching the substrate.

14. The apparatus according to claim 13, wherein the at least one chamber comprises one of a plurality of succeeding chambers with means for evacuating each of the succeeding chambers to draw off gases other than the activated nitrogen molecules passing therethrough towards the substrate.

15. The apparatus according to claim 14, wherein the nozzle comprises a restricted end of a tube, the tube being in the nitrogen delivery path, the first one of the corona-discharge electrodes being located within the tube, and the second of the corona discharge electrodes being located outside the tube, the nitrogen emergent from the tube into a corona discharge between the electrodes forming with the corona discharge a corona discharge supersonic free-jet.

16. The apparatus according to claim 15, wherein the second of the corona discharge electrodes is generally annular and surrounds the restricted end of the tube.

17. The apparatus according to claim 15, wherein the second of the corona discharge electrodes is downstream of the restricted end of the tube in the direction of nitrogen flow.

18. The apparatus according to claim 17, wherein the skimmer serves as the second of the corona discharge electrodes.

19. In a semiconductor manufacturing process, a method of applying a layer to a substrate comprising at least a semiconductor stratum; the method comprising:

(a) directing onto the substrate an activated molecule comprising at least:

(i) a first atom operative chemically to bond to an element at the substrate, and

(ii) a second atom operative to disassociate and leave the substrate removing heat caused by a reaction between the first atom and at least one substrate constituent in so-doing.

20. A method of forming a multi-layer semiconductor constituent comprising:

(a) providing a target substrate comprising at least a stratum of semiconductor material,

(b) producing a beam at least partially comprised of metastable activated nitrogen molecules, and

(c) impacting a surface of the target substrate with the beam of metastable activated nitrogen molecules.

21. The method according to claim 20, wherein the beam of metastable activated nitrogen molecules comprises diatomic nitrogen molecules.

22. The method according to claim 21, wherein step (c) comprises binding a first atom of the diatomic nitrogen molecules with at least one further element at the surface of the substrate in an exothermic reaction and releasing the heat of the exothermic reaction by release of a second atom of the diatomic nitrogen molecules.

23. The method according to claim 20 or 22, wherein the diatomic molecule is of the form $N_2A^3\Sigma_u^+$.

24. The method according to one of claims 20 through 22, wherein step (c) includes reacting the metastable activated molecule with a group III metal.

25. The method according to one of claims 20 through 22, wherein step (c) includes reacting the metastable activated nitrogen molecule with at least one of an element chosen from group consisting of Al, Ga and In.

26. The method according to one of claims 20 through 22, wherein step (a) comprises providing a substrate having a semiconductor stratum and an oxide layer, and step (c) comprises impacting the oxide layer with the beam of metastable activated nitrogen molecules.

27. The method according to any one of claims 20 through 22, wherein step (b) comprises producing the beam by introducing nitrogen in a corona discharge supersonic free-jet directed at the target substrate.

28. In a semiconductor manufacturing process, a method of applying a nitride layer to a substrate comprising at least a stratum of semiconductive material, including the steps of:

(a) directing a beam of metastable activated nitrogen molecules onto the substrate by:

(i) providing a corona discharge supersonic free-jet source (CD-SFJ);

(ii) supplying nitrogen to the CD-SFJ to produce the metastable activated nitrogen molecule beam;

(iii) locating the substrate in the path of the beam; and

(iv) introducing at least one further element operative in association with the activated nitrogen molecules to produce a nitride layer on the substrate.

29. A method of producing a film on a semiconductor substrate comprising:

(a) establishing in a vacuumized location a corona discharge across a set of corona discharge electrodes,

(b) creating a flow of diatomic, activated, metastable nitrogen molecules by directing pressurized nitrogen gas through a nozzle into the plasma discharge,

(c) collimating the flow of activated nitrogen molecules,

(d) positioning the semiconductor substrate in the collimatic flow of activated nitrogen molecules,

(e) reacting the activated nitrogen molecules with at least one other element at a surface of the substrate to grow a nitride layer on the surface by:

(i) exothermic reaction of one atom of each molecule thus reacting, and

(ii) disassociating a further atom and the one atom of each molecule thus reacting to dissipate the heat produced in the exothermic reaction.

30. The method according to claim 29, wherein step (b) includes pressurizing the nitrogen gas to a stagnation pressure of substantially 200 torr or greater.

31. The method according to claim 30, wherein step (a) comprises establishing the corona discharge at a location vacuumized to a pressure of less than 1 x 10 torr.

32. The method according to any one of claims 29 through 31, wherein step (b) further comprises creating in the corona discharge nitrogen molecules substantially only of the excited form $N_2A^3\Sigma_u^+$ and the ground state form $N_2X^1\Sigma_g^+$.

33. The method according to any one of claims 29 through 31, further comprising directing at least one further stream of collimated diatomic, activated, metastable nitrogen molecules to the surface of the substrate by concurrently performing the steps (a) to (d) by directing nitrogen gas under pressure to at least one further nozzle.

34. The method according to claim 29, further comprising the step of elevating the temperature of the substrate at least several hundred celsius degrees above ambient.

35. The method according to claim 34, wherein the step of raising the temperature of the substrate comprises raising the temperature to a temperature in the range from about 600°C to about 900°C.

36. Apparatus for producing a film on a semiconductor substrate comprising:

(a) means for establishing a vacuumized environment,

(b) means for establishing a corona discharge in the vacuumized environment,

(c) means for creating a supersonic flow of nitrogen gas into the corona discharge to create a supersonic jet of diatomic, activated metastable nitrogen molecules,

(d) means for collimating the jet of nitrogen molecules, and

(e) means for locating a target semiconductor substrate in the path of the collimated jet of nitrogen particles.

37. The apparatus according to claim 36, further comprising means for withdrawing background gases from around the collimated jet of nitrogen molecules.

38. The apparatus according to claim 36, further comprising means for supplying a group III metal to react with the nitrogen molecules at a surface of the substrate to grow a group III metal nitride film on the surface.

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